

Passive Autonomous Acoustic Monitoring of Marine Mammals: System Development Using Seaglider™

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LONG-TERM GOALS

This effort exists within a group dedicated to the use of autonomous underwater vehicles, and buoyancy-driven gliders in particular, to support Navy missions. The group generally uses the Seaglider™, developed at the Applied Physics Laboratory of the University of Washington (APL-UW), and develops or adapts instruments and glider behavior to support specific mission requirements. This group is informally called the Applied Seaglider™ Group, whose acronym, ASG, is also used to describe the Applied Seaglider™ itself.

This report describes ongoing efforts as part of the ONR Passive Autonomous Acoustic Monitoring (PAAM) program. The original long-term goals of the PAAM program were as follows.

- Perform persistent and autonomous passive acoustic monitoring of a 500-1000 square nautical mile Navy exercise area for presence of marine mammals.
- Monitor for three weeks prior to, three weeks during, and three weeks after a typical exercise.
- Detect, classify and localize (DCL) vocalizing marine mammals.
- Provide actionable information in a timely manner to the officer in tactical command to support marine mammal mitigation efforts.

Over the past year, the long-term goals of the ONR PAAM program have changed to concentrate on the DCL mission in support of monitoring of marine mammals, particularly in Navy operating areas.

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OBJECTIVES

With previous ONR funding (N00014-08-1-0309), we have enhanced the passive acoustic detection, recording, and on-board processing capabilities of Applied Seaglider™ (ASG), with particular attention to the automated detection and classification of beaked whale vocalizations. In particular, we have designed and built a new passive acoustic detection and recording system for ASG, and tested this system in the field several times.

The objectives of this program are to enhance detection and classification performance by using multiple hydrophones, improve the automated detection and classification (software) components, provide post-processed rough bearings to detected vocalizations, and successfully demonstrate the system in a long-duration mission in a relevant Navy operating area.

APPROACH

The program will continue to focus on automated detection, classification, and recording of beaked whale vocalizations, enhanced by multiple omni-directional hydrophones on the Seaglider™.

Our approach was, and continues to be, as follows.

- Treat the single-hydrophone PAAM electronics system as deployed at AUTC in June, 2010, and at SCORE in January, 2011, as a baseline.
- Test installation of additional omni-directional hydrophones to minimize signal obstruction by the Seaglider™ pressure hull, and afford the opportunity to get rough bearings to vocalizations in post-mission processing.
- Design and build a new (and final) revision of the PAAM electronics board.
- Enable multiple active channels on the PAAM electronics board.
- Continue to collaborate with Drs. David Mellinger and Holger Klinck at Oregon State University (OSU) on improved beaked whale detection and classification algorithms.

Key participants at APL-UW, in addition to the Principal Investigators listed above, were Bill Jump (hardware and system design engineer), Geoff Shilling (software engineer), Trina Litchendorf (ASG Lab), Angie Wood (ASG Lab), and Paul St. Laurent (ASG Lab). Drs. David Mellinger and Holger Klinck at OSU provided detection and classification algorithms, and consulted on mission planning and operations.

WORK COMPLETED

Initial hardware and software modifications were made to incorporate multiple omni-directional hydrophones onto the standard Seaglider™ PAAM configuration. The initial modification was a prototype installation of HTI-99-HF omni-directional hydrophones at the tip of each wing of a Seaglider™, as shown in Figure 1. The hydrophone cables were routed and lashed along the trailing edge of the wings. The lashings were covered by black tape in the prototype installation. The final configuration for the Seaglider™/PAAM hydrophones will be the three-channel system shown in Figure 2.

Flight tests were performed using Seaglider™ S/N 178 equipped with wingtip-mounted HTI-99HF hydrophones. The tests were done to verify the ability of Seaglider™ to achieve stable flight, with adequate speed through the water, in the presence of the additional drag caused by the wingtip-mounted hydrophones. No acoustic sampling was done during this initial flight test.

A final revision of the PAAM electronics board was designed, laid-out, and manufactured. This revision of the PAAM board contains a number of improvements primarily designed to provide more CPLD capacity. This CPLD capacity will offload the main ARM-9 processor from tasks associated with management of the digitization, buffering, and distribution of the acoustic data stream. This will leave more cycles available on the ARM-9 for the on-the-fly detectors and the subsequent execution of the classifier code.

RESULTS

The flight tests on Seaglider™ S/N 178 (SG178) carrying HTI-99-HF hydrophones mounted on each wingtip were completely successful. Several dives were made in the vicinity of Shilshole Bay, Puget Sound WA on 26APR2011.

The basic dive performance plot for one of the dives is shown in Figure 3. The dive profile was normal, although Seaglider™ S/N 178 was ballasted light for the operation, which resulted in slower descents and faster ascents than is typical. The Seaglider™'s specified vertical speeds were obtained with vehicle pitch angles well within normal ranges. Sufficient speed through the water was available to maintain heading control (course) and make progress over the ground against typical depth-averaged currents. All other Seaglider™ diagnostics shown in Figure 3 are within normal operating limits.

This positive result means that a Seaglider™ carrying wingtip-mounted hydrophones will be capable of normal dive profiles. The drag penalty, which will translate into an endurance penalty, is small enough that an open-ocean mission with many 1000m dives will be required for accurate assessment.

The final revision to the PAAM electronics board is complete. Boards have been built and populated with electronics to the new design. These boards are now undergoing testing. The main work remaining is to fully implement and test the multi-channel capability of these boards.

We plan to participate in a demonstration of the Seaglider™/PAAM system in FY2012, at a time and place to be determined in consultation with our ONR sponsors and program colleagues, and based on Navy needs and opportunities. We plan to deploy two Seaglider™/PAAM systems, one with multiple hydrophones, and one in the typical single-hydrophone configuration.

IMPACT/APPLICATIONS

The Seaglider™/PAAM detection and recording system has achieved an initial operational capability with a single omni-directional hydrophone. Additional omni-directional hydrophones will add spatial diversity to combat signal shielding by the body of the Seaglider™. The additional hydrophones will also constitute a limited acoustic array, with the ability to associate rough bearings with the detected vocalizations.

The Seaglider™/PAAM system has the frequency range, computational power and flexibility, and persistence to be capable of a wide range of passive acoustic detection and recording missions. It is especially suitable for higher-frequency applications, where hydrophones can be small and large acoustic aperture is not required. The multi-channel electronics and sophisticated computational capability make integrating lower-frequency systems feasible.

RELATED PROJECTS

The primary related project was the previous ONR-funded PAAM work, under N00014-08-1-0309, as mentioned above. That project performed the initial PAAM development, and carried out four major sea trials, including short deployments at both AUTECH and SCORE. It ended on 30APR2011. There are many related projects to use passive acoustics on autonomous platforms to detect, classify, and monitor marine mammals; some are funded as part of ONR's broader PAAM program, some are supported elsewhere.

Dr. David Mellinger at OSU is directly funded by ONR under the PAAM program to provide beaked whale detection and classification algorithms. Dr. Mellinger and his colleague Dr. Holger Klinck also provide consultation on the placement and use of the multiple hydrophones on the Seaglider™/PAAM system.

FIGURES



Figure 1. Seaglider™S/N 178 aft fairing with port wing and wingtip-mounted HTI-99-HF hydrophone. Aft is up in this picture; the hydrophone cable is routed and lashed along the trailing edge of the wing, then through a hole in the dorsal Seaglider™ aft panel. A mirror-image installation was done on the starboard wing. The lashing was covered by black tape during the initial field trial.



Figure 2. Seaglider™ S/N 178 with three HTI-99-HF hydrophones – one on each wingtip and one in the original position on the centerline.

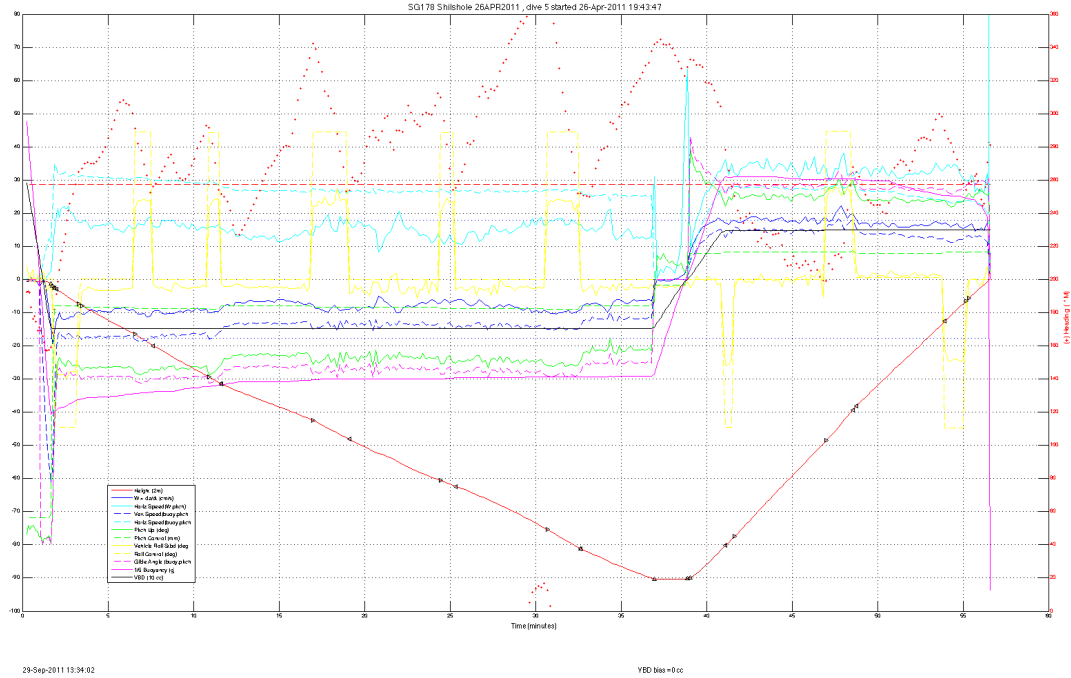


Figure 3. Plot of Seaglider™ S/N 178 dive 5 in Shilshole Bay, Puget Sound WA, on 26APR2011 with wingtip-mounted hydrophones. The horizontal axis is time, each tick mark is five minutes. The vertical axis carries various scales, but for the red curve, which is glider depth, each tick mark is 20 meters. Seaglider™ S/N 178 was ballasted light for this mission, hence the slower descent and faster ascent. Other quantities plotted on this curve are all within normal limits for Seaglider™ operations.